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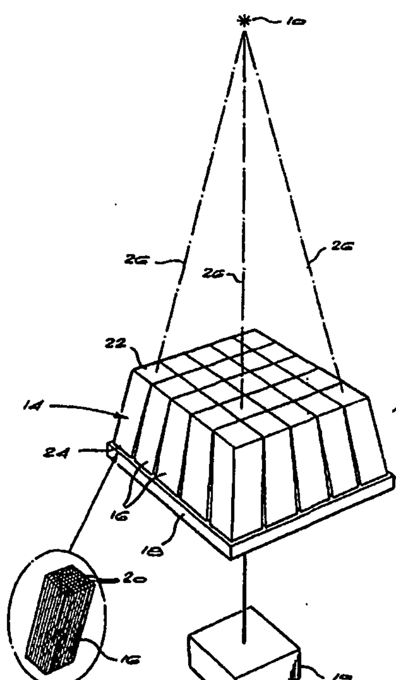
(54) Title: NEUTRON DETECTION APPARATUS

(57) Abstract

The invention concerns a neutron detection apparatus (12) which includes an assembly (14) of elongate scintillator elements (16). The longitudinal axes of the scintillator elements (16) are directed towards a fast neutron source (10) and each of them contains a scintillating material with which fast neutrons originating from the source (10) can interact to generate detectable light. The apparatus also includes a light detector (18) for collecting light generated in the scintillator elements (16).



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NEUTRON DETECTION APPARATUS

BACKGROUND TO THE INVENTION

THIS invention relates to a neutron detection apparatus.

The specification of South African patent application 94/10192 describes a fast neutron imaging technique for use in detecting the presence of a certain substance in a host body, for example a diamond inclusion in a particle of kimberlite. In the simplest form of the technique, individual kimberlite particles are irradiated with a beam of fast neutrons, i.e. neutrons which have a kinetic energy level of the order of mega-electron volts. An absorption image is obtained and from this detected image it is possible to determine whether the substance in question is present in the host particle. The neutrons should be monoenergetic, i.e. with a well-defined energy level which is at or near a resonant absorption energy level for the substance in question. For instance, in the case of detection of diamond in kimberlite, the neutrons may have a well-defined energy level of about 8 MeV which is at a resonant carbon absorption level and at which there is good contrast between diamond and kimberlite absorption.

The samples can also be irradiated with a fast neutron beam at two distinct energy levels, one of which is a resonant energy level for the substance in question and the other of which is a non-resonant level. In the case of detection of diamond within kimberlite, the neutron beam energy levels may, for instance, be 8 MeV and 7 MeV respectively. The absorption images

obtained at the two energy levels are subtracted from one another to yield a third image which is analysed for the presence of the substance in question.

In order to attain a suitably high processing speed to enable the technique described above to be used in on-line sorting of diamondiferous material, a highly efficient neutron detector is required.

Conventionally, radiation is detected using one of two techniques. In the first technique, the radiation which is to be detected impinges on a scintillating material, typically a phosphor. The light which is generated is observed by a light detector, such as a CCD camera, and is converted into an electrical signal.

In the case of a fast neutron beam, with which the present invention is specifically concerned, the generally employed technique involves impingement of the neutron beam on a target material including hydrogen-containing molecules. As a result of energy transfers attributable to collisions between the chargeless neutrons and the charged protons in the hydrogen nuclei, ionisation is caused to take place indirectly, and this is used to generate detectable light. The requirement that the target be hydrogen-rich normally leads to the selection of a clear plastics material mixed with a scintillating agent such as anthracene.

However, fast neutrons have great penetrative power and this requires the use of a thick target of the scintillating material in order to stop a sufficient proportion of the neutron beam. The disadvantage which is then encountered is that the increased thickness of the target leads to increased distortion of the light-generated image. Also, the radiation-to-light conversion process has relatively low efficiency and there are further losses which inevitably take place during light transmission to, and processing in, the CCD camera or other detector.

This combination of factors makes a conventional arrangement of this type impractical for use in high speed, on-line sorting of diamond-containing particles in diamondiferous material, eg diamonds within kimberlite host bodies.

SUMMARY OF THE INVENTION

According to the present invention there is provided a neutron detection apparatus which comprises an assembly of elongate scintillator elements the longitudinal axes of which are directable towards a neutron source and each of which contains a scintillating material with which fast neutrons originating from the source can interact to generate detectable light, and light detection means for collecting, from the scintillator elements, light generated in the elements.

In a preferred version of the invention, each scintillator element comprises a bundle of side by side, parallel fibres each containing the scintillating material. Typically the scintillator elements have divergent axes which meet at a common point which coincides, in use, with the neutron source. First ends of the elements which are in use closest to the neutron source may lie generally in a common plane and be closely adjacent or in contact with one another. Second ends of the scintillator elements which are in use furthest from the neutron source may also lie generally in a common plane, spaced apart from one another.

In another version of the invention the scintillator elements are individual fibres with divergent axes meeting at a common point which, in use, coincides with the neutron source. Ends of the fibres closest to the neutron

source are preferably closely adjacent to or in contact with one another and lie generally in a common plane. Opposite, second ends of the fibres which are furthest from the neutron source may be spaced apart from one another. In an alternative configuration, the fibres are of tapered shape and have second ends which are close to or in contact with one another.

The light detection means conveniently comprises a body, possibly of amorphous silicon, arranged adjacent ends of the scintillator elements which are in use furthest from the neutron source to collect light from those elements.

BRIEF DESCRIPTION OF THE DRAWING

The invention will now be described in more detail, by way of example only, with reference to the accompanying diagrammatic drawing which illustrates a neutron detection apparatus according to the invention.

DESCRIPTION OF AN EMBODIMENT

In the drawing, a fast neutron source is indicated with the reference numeral 10 and a neutron detection apparatus is indicated generally with the numeral 12.

The neutron detection apparatus 12 comprises a detector block 14 composed of a series of sub-blocks 16 and a light detection means 18. The numeral 19 indicates an electronic processor for analysing the light collected by the light detection means 18.

In this embodiment, each sub-block 16 of the block 14 is a scintillator element and comprises a multitude of thin, straight, single strand fibres 20 made of light-transmitting, preferably clear, plastics material and containing a suitable scintillating material. This could be anthracene, but is preferably Bicron BCF 12 (trade mark).

As is seen in the enlarged portion of the drawing, the individual fibres 20 are parallel to one another in each sub-block 16 and the sub-blocks are square in cross-section.

First ends 22 of the sub-blocks 16, which are closer to the neutron source 10, are shaped to lie in a common plane. Similarly, second ends 24 of the sub-blocks, which are furthest from the neutron source and adjacent the light detection means 18, are also shaped to lie in a common plane.

As indicated by the exemplary, imaginary lines 26, each sub-block is oriented in the block 14 so that its longitudinal axis is aligned with the neutron source 10. At their first ends 22, the sub-blocks 16 are in contact with one another to form a continuous, planar surface while at their second ends 24, the sub-blocks are spaced apart from one another. Thus the sub-blocks diverge from one another in a direction away from the neutron source. In practice, tapered spacers may be located between the sub-blocks towards and at their second ends.

In a typical arrangement, the block 14 is spaced from the neutron source by a distance in the range 0,5m to 1,0m and each sub-block 16 is about 10mm x 10mm in cross-section and has a length of about 75mm.

The light detection means 18 in this embodiment is in the form of a thin detector plate of amorphous silicon. The upper and lower surfaces of the

plate have dimensions matching the dimensions of the planar surface of the block 14 formed by the second ends 24 of the sub-blocks 16, and the thickness of the plate is typically of the order of 6mm.

In use, samples which are to be irradiated with fast neutrons, for instance kimberlite particles in an application of the method described in the specification of South African patent application 94/10192, are located adjacent the neutron source 10, between that source and the block 14. Neutrons transmitted and scattered by the particles are received by the individual fibres 20 of the sub-blocks 16 of the block 14 with the result that light is generated within those fibres as a result of the presence therein of the scintillating material. The light is transported by the fibres to the second ends 24 of the sub-blocks 16 where it is collected by the amorphous silicon detector plate 18 for analysis by the processor 19.

An advantage of the invention as described above is the fact that acceptable levels of optical resolution can be maintained, even with a large block 14 and detector plate 18. In the first place this is because the sub-blocks are aligned longitudinally with the neutron source 10 so that the individual fibres 20 are themselves generally aligned with the source. In the second place this is because of the small cross-sectional dimensions of the fibres 20 making up the sub-blocks 16. These factors combine to ensure that the straight neutron trajectories do not result in significant numbers of neutrons crossing the boundaries between adjacent fibres 20, i.e. there is little cross-talk between adjacent fibres.

In the embodiment described above, the individual fibres 20 are bundled together to form the sub-blocks 16. It is however within the scope of the invention for the block 14 to be composed of a multitude of individual, discrete fibres 20 each aligned with the neutron source. In this arrangement,

the individual fibres would diverge from one another in a direction away from the neutron source so that, while they are close together or in contact with one another at their ends closest to the source, they are spaced apart at their ends remote from the source.

As an alternative, the fibres could themselves be tapered in shape so as to be in contact with one another at both ends.

For ease of construction, it is however preferred to bundle the fibres together to form the sub-blocks 16 which can then be assembled to form the block 14, as illustrated in the drawing.

Since the light from the scintillating material can be very weak it must be detected or amplified before the image is demagnified for ultimate detection or viewing. Specific mention has been made of the use of a thin plate of amorphous silicon as a light detection means. This permits the detection of full sized images without minification losses. Other forms of light detector are however also within the scope of the invention. For instance, large sized image intensifiers can be used to amplify the light, permitting further image size reduction and an adequate detection capability.

CLAIMS

1.

A neutron detection apparatus which comprises an assembly of elongate scintillator elements the longitudinal axes of which are directable towards a neutron source and each of which contains a scintillating material with which fast neutrons originating from the source can interact to generate detectable light, and light detection means for collecting, from the scintillator elements, light generated in the elements.

2.

A neutron detection apparatus according to claim 1 wherein each scintillator element comprises a bundle of side by side, parallel fibres each containing the scintillating material.

3.

A neutron detection apparatus according to claim 2 wherein each scintillator element has a rectangular cross-section.

4.

A neutron detection apparatus according to claim 3 wherein each scinillator element has a square cross-section.

5.

A neutron detection apparatus according to any one of claims 2 to 4 wherein the scintillator elements have axes which are divergent.

6.

A neutron detection apparatus according to claim 5 wherein the axes of the scintillator elements meet at a common point which coincides, in use, with the fast neutron source.

7.

A neutron detection apparatus according to any one of claims 2 to 6 wherein, in the assembly of scintillator elements, first ends of the elements which are in use closest to the neutron source lie generally in a common plane and are closely adjacent or in contact with one another.

8.

A neutron detection apparatus according to claim 7 wherein second ends of the scintillator elements which are in use furthest from the neutron source also lie generally in a common plane but are spaced apart from one another.

9.

A neutron detection apparatus according to claim 1 wherein the scintillator elements are individual fibres with divergent axes.

10.

A neutron detection apparatus according to claim 9 wherein the axes of the fibres meet at a common point which, in use, coincides with the fast neutron source.

11.

A neutron detection apparatus according to either one of claims 9 or 10 wherein the fibres have first ends which are in use closest to the fast neutron source, which are closely adjacent to or in contact with one another and which lie generally in a common plane.

12.

A neutron detection apparatus according to claim 11 wherein the fibres have second ends which are in use furthest from the fast neutron source and which are spaced apart from one another.

13.

A neutron apparatus according to claim 11 wherein the fibres are of tapered shape and have second ends which are in use furthest from the fast neutron source and which are close to or in contact with one another.

14.

A neutron detection apparatus according to any one of the preceding claims wherein the scintillating material is Bicron BCF 12 (trade mark).

15.

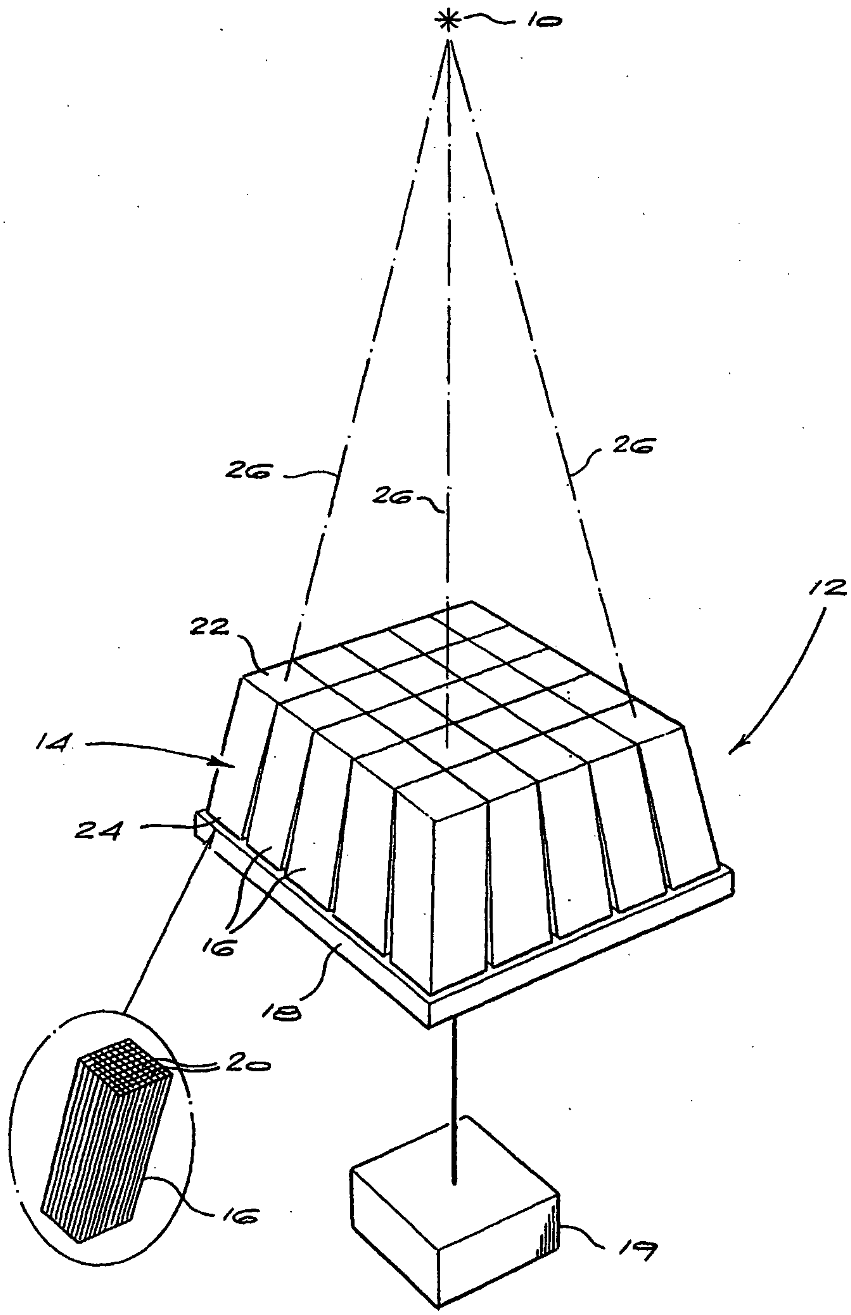
A neutron detection apparatus according to any one of claims 1 to 13 wherein the scintillating material is anthracene.

16.

A neutron detection apparatus according to any one of the preceding claims wherein the light detection means comprises a body arranged adjacent ends of the scintillator elements which are in use furthest from the fast neutron source to collect light from those elements.

17.

A neutron detection apparatus according to claim 16 wherein the body is made of amorphous silicon.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INTERNATIONAL SEARCH REPORT

Into onal Application No
PCT/IB 99/01817

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01T3/06 G01T5/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01T G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 308 986 A (WALKER JAMES K) 3 May 1994 (1994-05-03) abstract column 1, line 13 - line 15 column 3, line 5 - line 43 column 4, line 34 -column 5, line 2 column 8, line 10 -column 9, line 35 figures	1,2,4,7, 16
A	US 5 818 054 A (RANDERS-PEHRSON GERHARD ET AL) 6 October 1998 (1998-10-06) abstract column 5, line 64 -column 6, line 15 column 8, line 1 - line 18 figures	1,6

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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14 February 2000	21/02/2000

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
P,X A	US 5 880 469 A (MILLER THOMAS GILL) 9 March 1999 (1999-03-09) abstract column 4, line 16 - line 30 column 4, line 48 - line 53 column 6, line 27 - line 65 figures -----	1,2,4,7, 16 14

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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